THE POLYGRAPH

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The Polygraph

The use of such an instrument as a "lie detector" raises two types of question: scientific and ethical. Some answers to the first kind of question clearly point to the greater significance of the second

by Burke M. Smith

The Bedouins of Arabia once required conflicting witnesses to lick a hot iron; the one whose tongue was burned was considered to be lying. The ancient Chinese, it is said, made someone who was being questioned chew rice powder and spit it out; if the powder was dry, the suspect was guilty. In ancient Britain a suspect who could not swallow a "trial slice" of bread and cheese was also found guilty. All these tests were based on the early observation of a physiological change that often accompanies emotional tension: the flow of saliva decreases and the mouth becomes dry. Today too physiological changes are sometimes taken as a sign that the person in whom the changes occur is not "telling the truth." The changes are measured—rather more accurately than by a hot iron, rice powder or bread and cheese—by the device called the polygraph or, quite incorrectly, the "lie detector." Such devices are used in law enforcement and private investigation and by government and industry for checking the reliability of employees. In the past few years both the methods of "lie detection" and the polygraph itself have been subjected to increasingly critical scrutiny.

In reality the use of the polygraph in the effort to detect deception is only one rather special application of one version of a broad class of instruments. The word "polygraph" correctly describes any device that writes a number of things, that is, an instrument that records several events or processes at once. A device that simultaneously records temperature, humidity and barometric pressure is a polygraph; so is one that records engine revolutions and oil pressure. The term is commonly applied, however, to instruments that record various measurements of physiological activity in medical diagnosis, personality studies and other psychological or physiological research. The "lie detector" polygraph is a simple version of such an instrument.

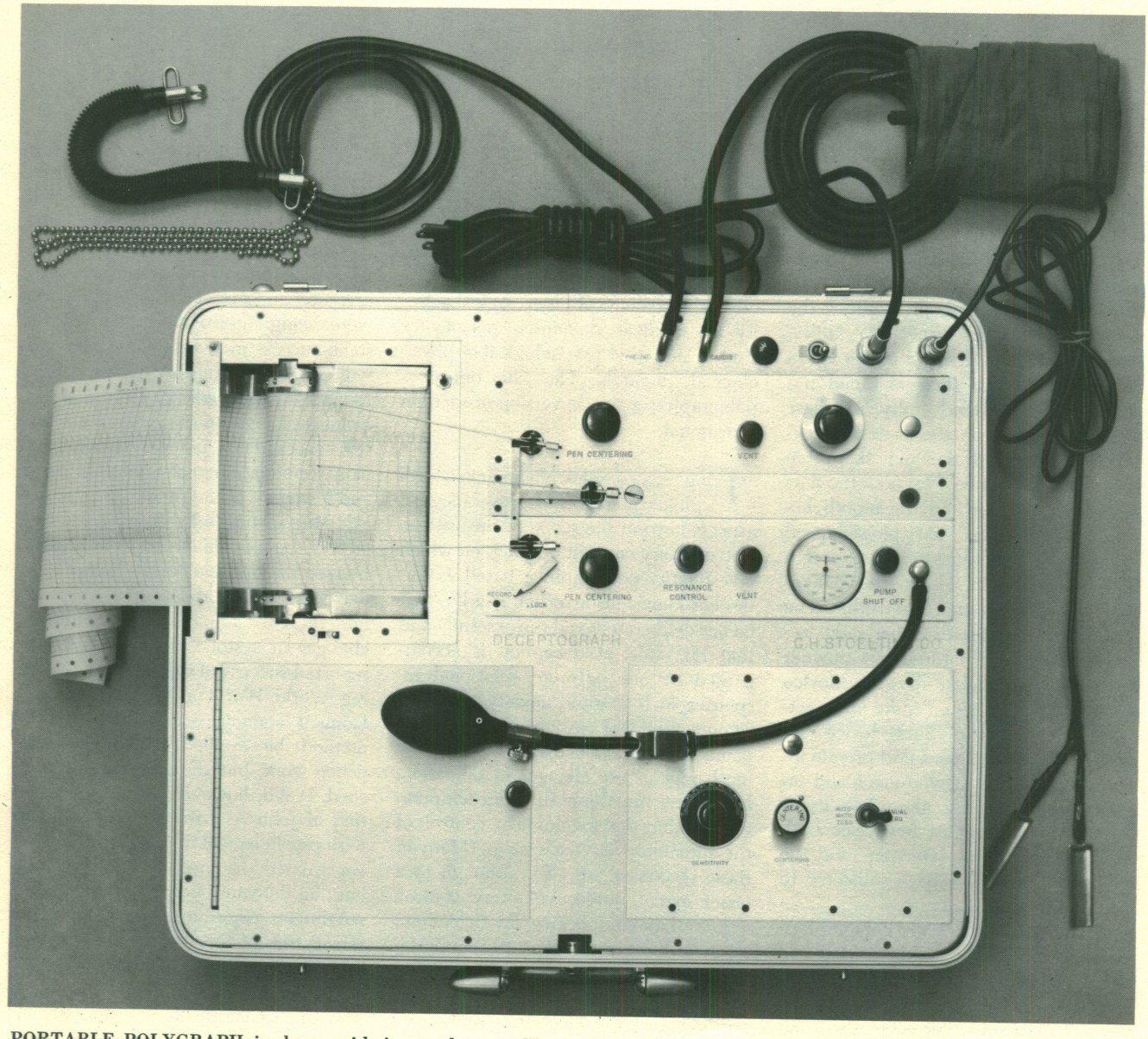
"Lying" is a complex phenomenon with philosophical and psychological aspects beyond the scope of this article. The ordinary concept of lying, on which investigative polygraphy is based, is that the liar knows his assertion is a lie, that he lies deliberately and purposefully and that his effort at deception is accompanied by one or more emotional responses such as guilt, anxiety and fear. These emotional responses are accompanied by physiological responses—the most obvious are changes in salivation, heart rate, breathing and skin temperature—under the involuntary control of the autonomic nervous system. (Many of these responses are also, although to a lesser extent, under voluntary control, a fact that complicates lie detection.) Some of the grosser physical manifestations of emotional tension are hesitation, stammering, fidgeting, perspiration and reddening of the face. It is such clues that almost automatically come to the mind of anyone who is trying to decide if someone else is telling the truth.

The first attempt to record with instruments the physiological accompaniments of the emotional experience of lying was made in 1895 by the Italian criminologist Cesare Lombroso. He measured changes of pulse rate and blood pressure in suspected criminals who were being interrogated, and reported some success in identifying guilty individuals. In 1914 another Italian, Vittorio Benussi, announced that he was able to connect changes in the rate of breathing with deception. The following year William Moulton Marston, a criminal lawyer and a student of the American psychologist Hugo Munsterberg (who had suggested the possibility of detecting lies by recording physiological changes), undertook research at Harvard University into the correlation between lying and changes in systolic blood pressure. He reported successful results in 1917. During World War I a National Research Council committee proposed that his method be applied in counterintelligence work, but the idea was not pursued. It did, however, attract the attention of John A. Larson, a police officer with psychological training, who in 1921 constructed the forerunner of the present "lie detector" polygraph. It made a continuous recording throughout an interrogation of the three processes dealt with by Lombroso, Benussi and Marston—blood pressure, pulse rate and respiration. Leonarde Keeler, an associate of Larson's on the police force in Berkeley, Calif., refined the device and went on to develop polygraph-interrogation

techniques in the crime detection laboratory at Northwestern University.

The Keeler instrument, in one version or another, has become the standard commercial polygraph: a simple, compact and often portable machine that records pulse rate, relative blood pressure, the rate and depth of breathing and often the resistance of the skin to the conduction of electricity. The cardiac variables—pulse rate and relative blood pressure—are picked up by a pressure cuff such as physicians use to take absolute blood pressure, placed around the upper arm and inflated so as to impede but not quite cut off circulation. Changes in the pressure of the blood flowing through the brachial artery are transferred to the recording pen by the column of air in a rubber tube; individual pulses show up as more rapid fluctuations superposed on the blood-pressure curve. The rate and depth of breathing are sensed by an accordion-like pneumatic device fastened around the chest. Skin resistance, variously referred to as galvanic skin response (GSR), psychogalvanic response (PGR) and electrodermal response (EDR), is detected by two electrodes placed on the fingers or other parts of the hand. A small electric current, made to flow through the electrodes and through an arbitrary resistance and a galvanometer, varies with changes in the resistance of the skin. The skin response is associated with the sweating of the palms that comes with tension but is not due simply to increased activity of the sweat glands. Its exact nature is still under investigation, but it apparently involves a number of electrical changes in the skin, including polarization of the sweat gland membranes.

Although a few practitioners still call the commercial polygraph the "lie detector," it is generally agreed that the instrument itself records not lies but physiological changes. Any detecting of lies is done by the examiner, the person who conducts the interrogation. A great deal depends, therefore, on the technique of examination, and this varies widely with different examiners and different "systems." The examining session is conducted in an atmosphere that is inevitably at least somewhat tense, so that the examiner's first effort is to get the subject to relax and to explain to him in some detail the procedure that will be

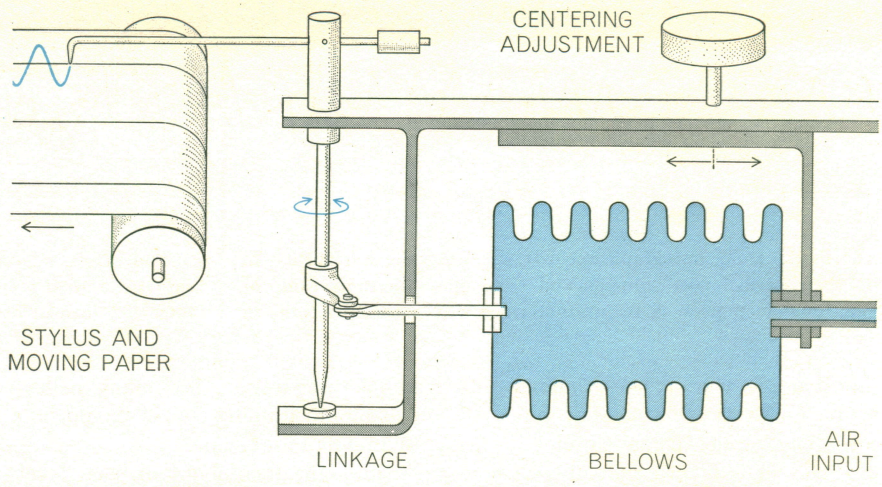


PORTABLE POLYGRAPH is shown with its attachments. The corrugated tube at the top left is placed around the chest to measure respiration. The cloth cuff (*top right*) senses blood pressure and pulse. The cable and finger electrodes (*right*) are for the instrument that measures the galvanic skin response. The three pens record (*top to bottom*) respiratory, skin and cardiac responses.

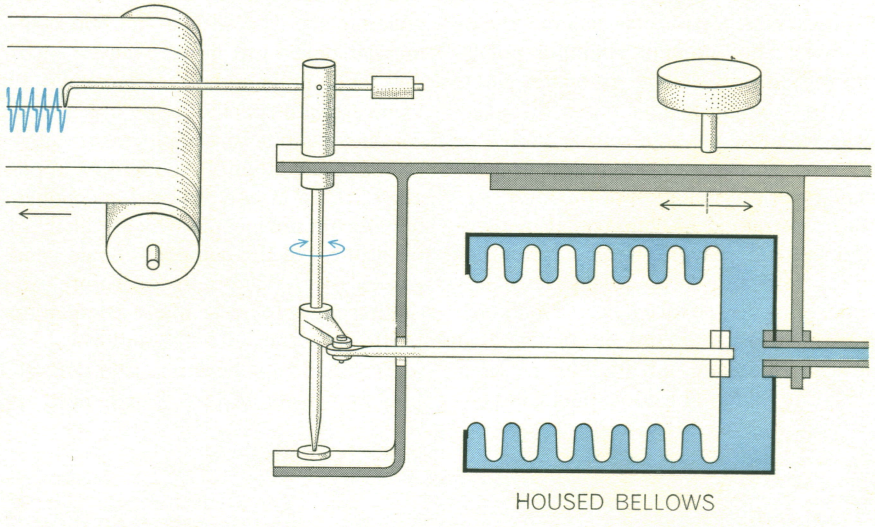
followed. Many practitioners conduct a rather full preexamination interview during which material is gathered for neutral "control" questions. Usually all the questions that will be asked during the examination proper are gone over in advance; among other things, this makes it possible for the subject to "clear" himself with regard to the critical questions. For example, it is desirable that he first admit to having once taken money from his little brother or a former employer so that he can later give an unequivocal answer to a question such as: "Apart from what you told me before, have you been stealing money?" Throughout the period before the examination it is common practice to impress the subject implicitly or explicitly with the idea that "the machine cannot be beaten."

Finally the subject is seated in a special chair and the various sensors are attached to him. The polygraph is turned on and the recording pens are adjusted to a normal base line. Then the series of carefully worded questions, each answerable by "Yes" or "No," is read to the subject; a marker is placed on the record for each question and the answer is jotted down. In most techniques "critical" questions are interspersed among "neutral" ones, the assumption being that the machine will record greater fluctuations from normal when the subject answers critical questions untruthfully. A substantial interval—up to a minute or so—is allowed between questions so that the traces can return to the base line. Often the entire examination is repeated after a period during which the examiner may try to clarify any ambiguous points. New questions can be added to achieve special objectives. For instance, in a "peak of tension" test the examiner can try to determine the location of a crime by suggesting various sites or progressively narrowing circles and watching for signs of increasing and decreasing tension in the subject.

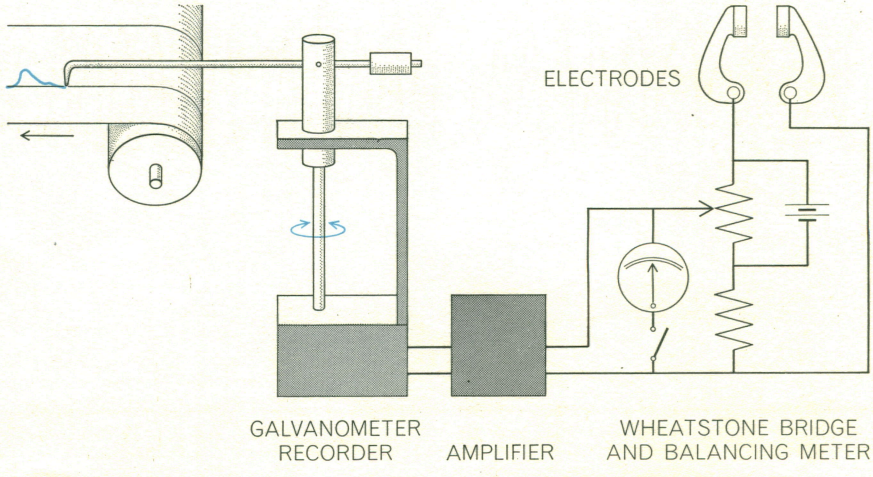
Once the record is obtained there are several things that can be done with it. One practice, which is certainly not rare, is simply to show the subject some oscillations on the tape, accuse him of a lie and thereby elicit a confession. The genuine interpretation of a record requires a good deal of technique. It is seldom that a lie is clearly indicated by distinct changes in the cardiac, respiratory and galvanic-skin-response traces; the variations are usually small, and often they are mutually contradictory. There are various systems for interpreting records, all relying on visual scanning of the traces and each taught by a different polygraph school or institute. There is considerable



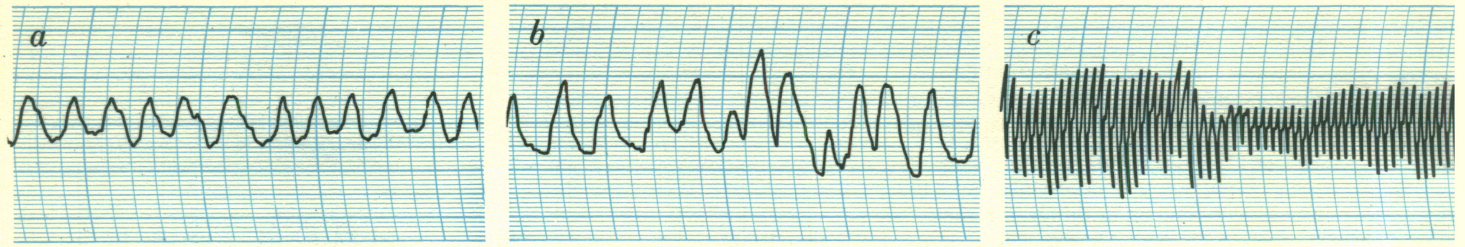
RESPIRATION recorder operates by dead-air displacement. An accordion-like tube fitted to the subject's chest is connected to the thin-walled metal bellows. As the subject inhales or exhales, air (*color*) is withdrawn from or returned to the bellows, rotating the vertical shaft that carries the pen. The pen is centered by moving the bellows assembly manually.



BLOOD PRESSURE can be recorded by a similar system but requires a "housed bellows" to withstand the air pressure in the measuring cuff around the subject's arm. When the cuff has been inflated (with the rubber bulb seen in the photograph on the opposite page), the pen is centered. Changes in blood pressure affect the volume of the cuff and thus the pressure in the bellows. The pen therefore records the pulse rate and relative blood pressure.



SKIN RESPONSE is recorded by a unit that includes a Wheatstone bridge and a galvanometer. The bridge is balanced by adjusting a variable resistance to match that of the subject's skin. Any subsequent changes in current across the electrodes are amplified and recorded.



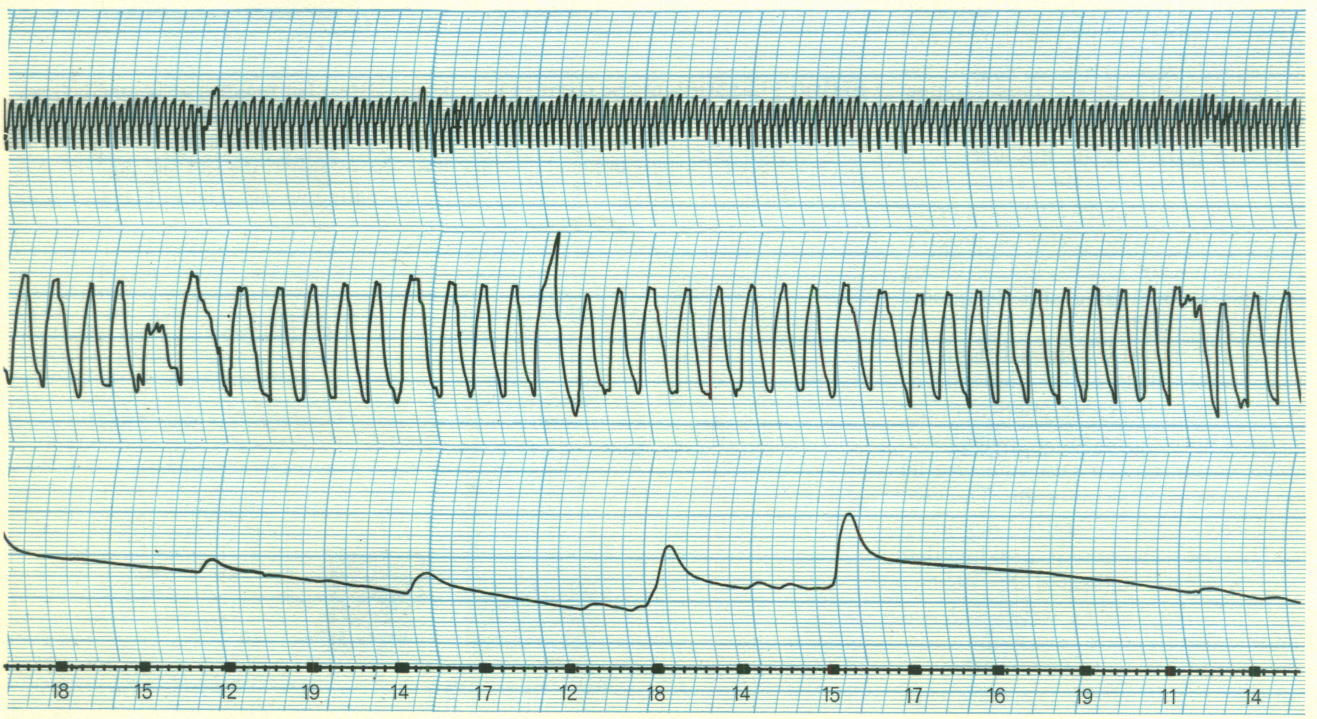
SAMPLES from polygraph records illustrate the variability in traces from different subjects and some possible indications of emotional responses. A respiratory trace may show variations in period (*a*) or magnitude (*b*). Blood-pressure curves (made in this case by a plethysmograph, which measures blood volume in a fingertip, instead of by an upper-arm cuff) can vary widely. An

intuition involved; as one examiner puts it, the analysis is "a Gestalt process." Most polygraphers come to prefer one index and may ignore the others; some work with instruments that measure only two or three of the four usual indexes.

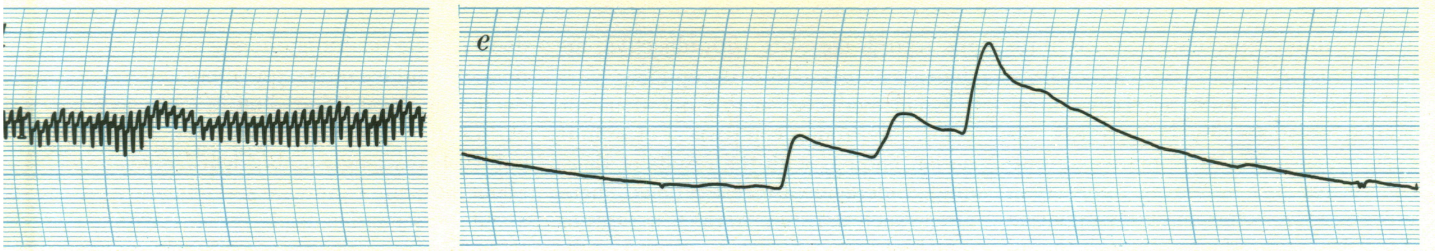
Polygraph operators, of whom there are an estimated 2,000 to 3,000 in the U.S., vary widely in their general educational background and training in polygraphy. Some are college graduates and a few are lawyers or have other advanced degrees; most are high school graduates with no academic background in psychology or physiology. For the most part they are trained at commercial or Government-run polygraph schools for between four and seven weeks. It is possible, however, to take a correspondence course instead. There is no general agreement among polygraphers on what constitutes adequate educational and on-the-job preparation, but many believe a six-month training course should be a minimum requirement.

Although the polygraph was developed as an aid in police work, enterprising practitioners have long since discovered new applications for the device and since about 1950 the polygraph has become firmly established in industry and government. There are some 500 commercial polygraph firms. Many companies retain polygraph examiners not only to investigate specific losses but also to conduct routine preemployment interviews in an attempt to identify applicants with a criminal record, alcoholics, homosexuals or people who are likely to be disloyal to the company. Some companies give a polygraph test before promoting an employee. Many companies, particularly those whose employees regularly handle money, administer periodic polygraph tests "to keep them honest."

In 1964 and 1965 a Congressional subcommittee headed by Representative John E. Moss of California investigated the use of polygraphs in the Federal Government. The committee found that 19 agencies had a total of at least 512 polygraphs and 639 authorized operators who had conducted some 20,000 examinations in 1963. (These figures do not include the Central Intelligence Agency or the National Security Agency, presumably the biggest users.) Some of the tests were administered in the course of criminal investigations; others were for security purposes or simply for personnel screening. The report charged that most Federal polygraph operators lacked proper qualifications, that administrative controls were weak and that employees' rights were frequently violated. The committee concluded: "Polygraph testing is extensive and growing in the Federal Government. All too often



RESPIRATION AND SKIN responses are of interest in this record from an experiment in which subjects picked a number and then tried to conceal its identity from the examiner. In this case the number was 15. The skin-resistance trace (*bottom*) peaks at 15. Breathing (*middle*) is cut short and then slowed (*left*) or merely slowed (*right*). Anomalous respiration peaks may indicate movement.



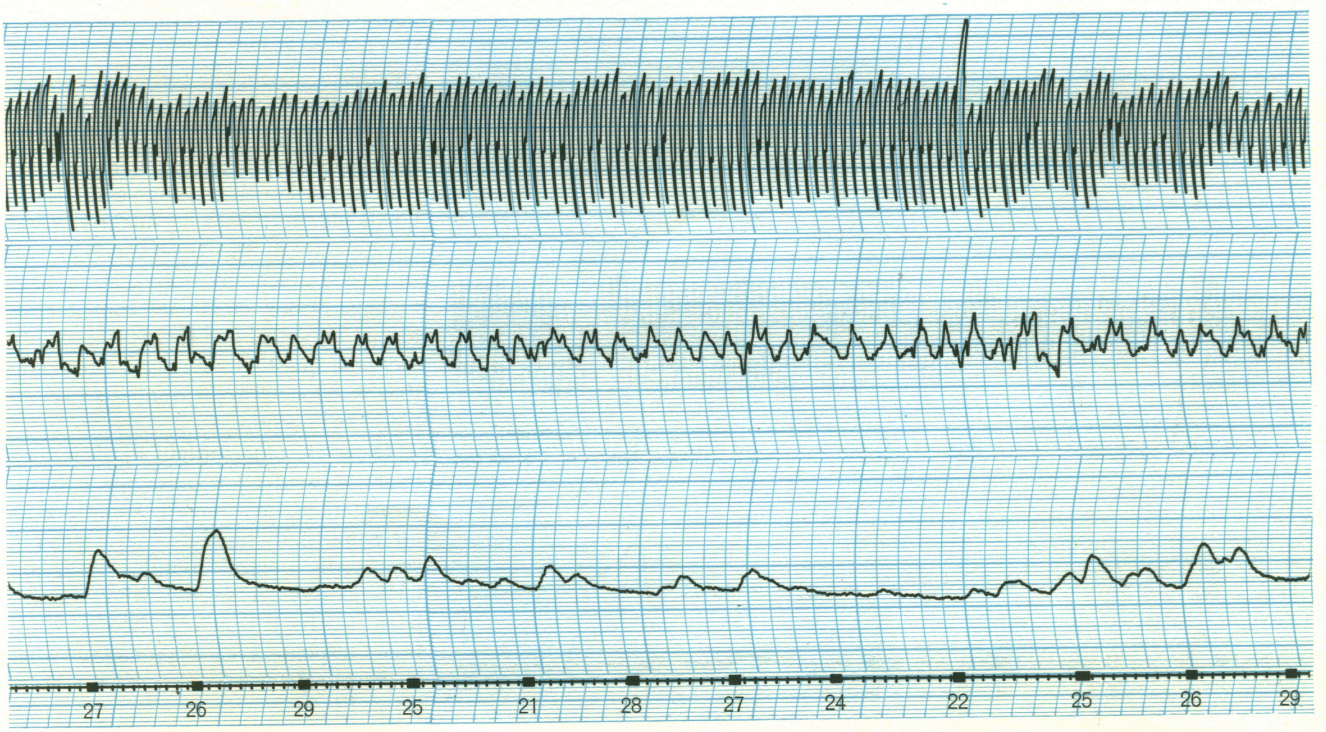
emotional response may be indicated by a constriction (*c*), which indicates a decrease in systolic and increase in diastolic pressure, or by a general rise in pressure (*d*). The galvanic skin response, which is not superposed like the others on a cyclical curve, may be easier to read, as in the "peak of tension" test the result of which is illustrated (*e*). This response is not dependably present, however.

it is used on trivial matters." It recommended, among other things, that use of the polygraph be prohibited "in all but the most serious national security and criminal cases." Four months later the Department of Defense did issue a directive sharply reducing the use of the polygraph, regulating the conduct of examinations and setting higher standards for polygraph examiners.

Outside the Federal Government the polygraph remains largely uncontrolled. Evidence from the polygraph record is not admitted in any court, but the device can be used freely for investigations in most jurisdictions. In 1959 Massachusetts adopted a law forbidding employers to require job applicants to take a polygraph test as a condition of employment; since then Oregon, California and Alaska have passed similar laws. So far only Illinois, Kentucky and New Mexico have adopted legislation requiring polygraph operators to be licensed. Some of the training schools come under the supervision of state regulatory boards, but standards vary widely.

The complaints against investigative polygraphy fall into two broad categories: scientific and ethical. Polygraphy is sometimes called "scientific lie detection"; its critics often suggest that this is a misnomer. A scientific technique, they maintain, must rest on a theory and be developed through experimentation and findings expressed in statistics. It should utilize the best tools available and be refined through continuing research. None of this is true of polygraphy. There is, to be sure, a related scientific discipline: psychophysiology. Whereas the standard polygraph has not basically changed since the 1920's, polygraphs designed for research have become much more sophisticated. Some of them can record data on 20 or more physiological processes at once. Varied and more precise sensors have been developed to detect physiological changes; electronic circuitry has been introduced to transmit the changes through several stages of amplification to the recorder; in some cases the data can be immediately processed and analyzed by computer. A broad range of additional physiological responses has been investigated: changes in brain waves, skin temperature, muscle potentials, hand and finger tremors, eye movements, pupil diameter, salivation and even stomach motions.

As research instruments polygraphs have produced valuable data on the reactions of people to various kinds of stress, including the effects of drugs as well as of emotional stimulation. One of the interesting findings is that there are large individual differences in responsiveness to identical stresses. People



CARDIAC AND SKIN responses are the most pronounced ones on this record made, like the others on these two pages, by Joseph F. Kubis of Fordham University. In this test the subject was lying as to number 26. The skin response peaks each time the number is called; the blood-pressure change (*top*) is fairly clear the first time. The cardiac change at 22 is probably from an arm movement.

tend to exhibit repeatable patterns of response: for one person the cardiovascular system may quite regularly mirror emotion most sensitively, whereas another person may be primarily a "pulmonary reactor." Moreover, some organ systems "adapt"—become less responsive—after a number of stimulations. In any individual, therefore, certain autonomic responses are better indexes of emotion than others. This and other findings should be of interest to polygraph practitioners, but there has apparently been little or no crossover from scientific to investigative polygraphy. And the scientists, perhaps not surprisingly, have done little research bearing directly on the detection of deception.

The lack of research gives rise to the major question about investigative polygraphy: How well does it work? To be effective an instrument or a test must be valid and it must be reliable. Validity is the extent to which something measures what it is supposed to measure: the Rorschach test, for example, can be considered a valid test of personality only insofar as its results show positive correlations with the results of other personality tests and with experience. Since the polygraph as an instrument measures not lies but physiological changes, the question is how well the results of the total polygraph examination—the interrogation, the record and the interpretation of the record—correlate with objective, independent measures of deception.

Good evidence on this question can come only from a comparison of examination findings with the results of thorough, independent investigations. There are no such statistics. In the few cases in which effectiveness has been evaluated, confessions of guilt or of attempts to deceive have been commonly taken as criteria for determining validity. The trouble with this is that in many cases the confession may have come before or during the examination, or even after an inconclusive examination, which is thereupon said to have been conclusive! Moreover, it is well known that confessions are not always reliable.

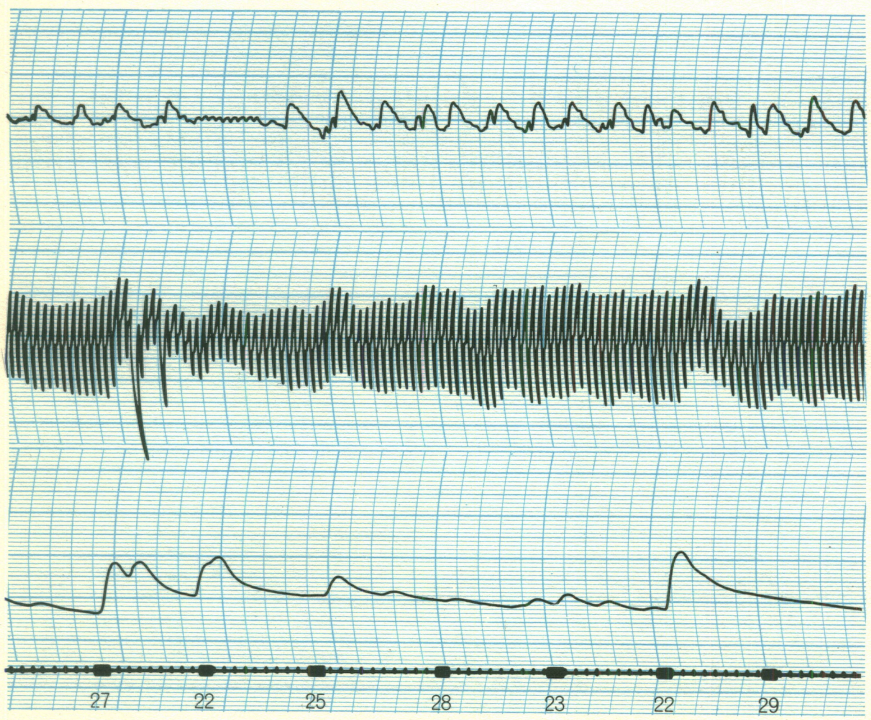
One such case, which I investigated with H. B. Dearman, then of the University of Virginia School of Medicine, involved a young bank manager who was subjected to a "routine" polygraph examination. He showed a violent response to the question: "Have you ever stolen any money from the bank or its customers?" On a peak-of-tension test to specify the amount of money stolen, he showed strong reactions at the mention of the sums $800 and $1,100. He could not remember taking any such sum but, confused and convinced of the machine's infallibility, he confessed to having stolen $1,000 and told how he must have done it. The bank's auditors could find no such shortage or manipulation, and so the manager was referred for psychiatric examination. Dearman found that the patient had strongly ambivalent feelings about his mother and wife and felt guilty about personal financial dealings with them involving the sums of $800 and $1,100. Both the mother and the wife were customers of the bank. Dearman therefore concluded that it was the phrase "or its customers" in the critical polygraph question that had elicited the violent reaction.

To test this hypothesis we had a different polygraph examiner administer a second test with the same questions that were used on the first, and also new questions in which the words "bank" and "customers of the bank" were separated. Once again the examiner decided the manager was lying and was guilty of theft. Careful study of the polygraph record showed, however, that consistent emotional reactivity was displayed only to questions in which the word "customers" appeared.

Clearly the original polygraph results were not valid. It was not deception but an autonomic response to unconscious attitudes that had caused the strong polygraph reactions. The same effect was shown on a trivial question included as a control: "Do you drink coffee?" The manager answered, quickly and truthfully, "Yes," but the polygraph showed a strong emotional reaction. The young man could not explain this, but psychotherapy revealed that coffee-drinking had been absolutely forbidden during his childhood; the memory of that prohibition had been lost or suppressed but remained potent. In much the same way a confirmed smoker who thinks he should stop smoking might respond emotionally to the question "Do you smoke?" In fact, any word that happens to have strong emotional connotations for an individual and that is included in a critical question may elicit a response that is erroneously attributed to an attempt at deception.

There are other pitfalls that can lead to "false positive" or "false negative" interpretations of a record. Some people are emotionally highly sensitive even to supposedly neutral stimuli; others are unresponsive. A person who believes what he says is true may show no emotional response even when he says what is objectively untrue. A person who is ashamed of his name may show emotion when he quite truthfully answers "Yes" to "Is your name Adolf Schicklgruber?"

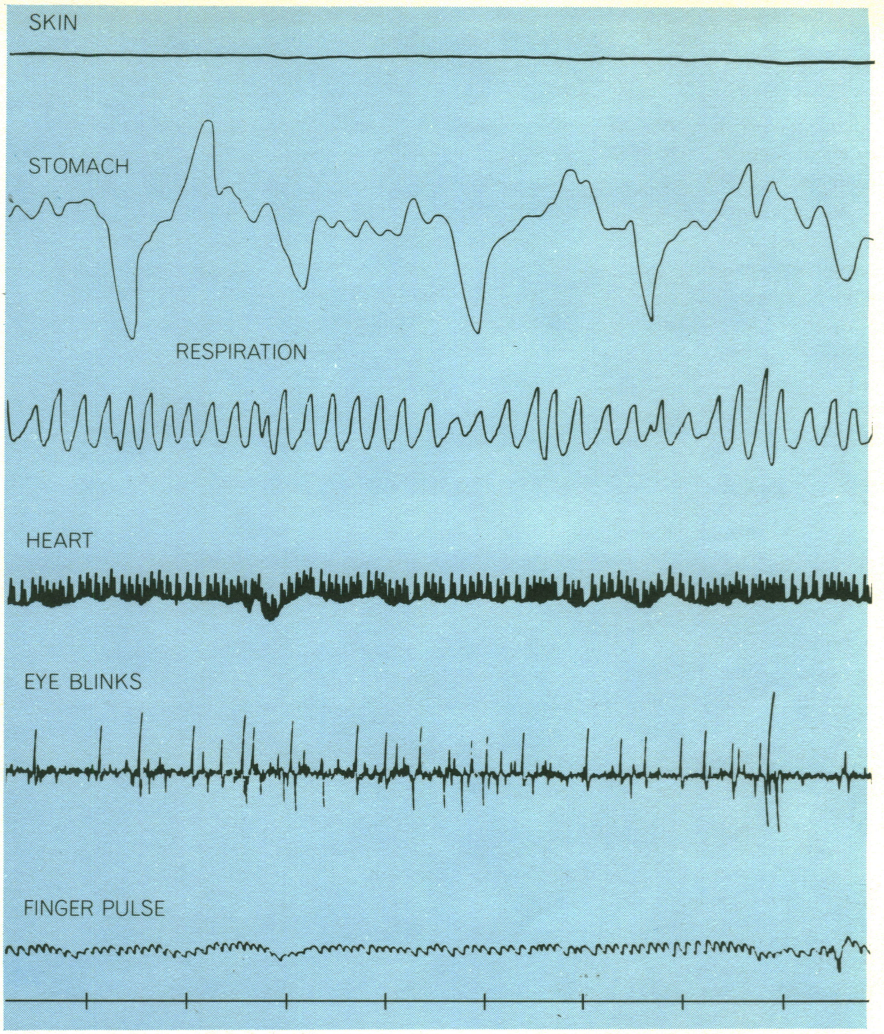
To be effective a test must be not only fundamentally valid but also reliable,



COUNTERMEASURE is illustrated by a record from Kubis' series. The subject lied about number 27. He simulated lying about number 22 by tensing his toes. The respiratory trace (*top*) shows that he held his breath as he undertook the first countermeasure. He was able to produce sizable reactions in the cardiac (*middle*) and skin-resistance (*bottom*) traces.

that is, it must be capable of being repeated by different people and under different circumstances and yield about the same results. It is difficult to assess reliability in polygraphy because there are no absolute measures or even any hard numbers; there are only ups and downs, visually scanned, so that it is impossible to compare two sets of results with any precision. There are certainly a number of potential sources of inaccuracy. The instrumentation is relatively crude. It is known that reactivity varies with the "initial value" of a physiological process, but the polygrapher does not know that value. Room temperature and humidity and the subject's physical condition affect the record but are seldom taken into account. A badly phrased question may complicate an answer (as in the case of the "bank or its customers" question put to the bank manager). Even the tone of the examiner's voice or his manner as he asks a question can influence the nature of the response; few investigative polygraphers have the training, skill, interest or time required to recognize and rectify such sources of error. Finally, there is the possibility of countermeasures. The machine can be "beaten" by a subject who either tenses some muscles or concentrates on some exciting image or thought and thereby creates a false-positive response to obscure his critical responses.

In spite of all these problems, a polygraph interrogation by an experienced examiner certainly has a better-than-chance probability of arriving at a correct determination of truth or deception. The question is: How much better? Polygraphers claim anywhere from 95 to 100 percent accuracy but, as I have indicated, they have no valid statistics to support their claims and few scientists have sought to investigate the matter. Joseph F. Kubis of Fordham University did conduct a study of the methods of polygraphy in 1962. His major experiment involved a sham theft situation: the examiners had to distinguish a volunteer "thief" from a "lookout" and an "innocent bystander" on the basis of polygraph interrogations. Kubis found that the examiners correctly identified the volunteers' roles in 73 to 92 percent of the cases; in 112 sessions only two "innocent bystanders" were incorrectly called "thieves." The galvanic skin response provided the highest accuracy (about 90 percent); the respiratory and cardiac indicators yielded figures of 60 to 70 percent. In another experiment, in which parolees were told to lie twice about their criminal records, examiners were able to detect both lies in 40 percent of the cases, one lie in 48 percent and neither lie in 12 percent. In a countermeasure experiment the subjects were able to reduce the examiners' accuracy scores from 75 percent in a control test to 25 percent by thinking of something exciting or upsetting and to 10 percent by tensing their toe muscles.



MULTICHANNEL RECORDING is illustrated by this record made by Richard A. Sternbach of the University of Wisconsin Medical School, who was measuring autonomic responses of children watching a movie. In addition to skin resistance, respiration and finger pulse, he recorded stomach movements with a magnetometer that followed the motions of a tiny magnet the children swallowed, heart rate with an electrocardiograph and eye blinks with an electroencephalographic lead that sensed eye-muscle impulses.

Beyond the scientific questions about polygraph interrogation there are the ethical considerations. First of all, to say or imply that the machine is infallible is to use a lie to detect a lie. To elicit admissions through fear of the machine or misrepresentation of its record is to force a confession. (Incidentally, although evidence based on polygraph results is inadmissible in court, a confession obtained in the course of a polygraph examination may be admissible.)

A person undergoing even a routine polygraph test may inadvertently reveal, particularly in the preexamination interview, information about himself that he would not voluntarily have revealed. The polygraph operator is not a physician or a lawyer or a priest; he is anxious to pass on whatever details he can find to his superior or to the man who has hired him. If his findings cast doubt (rightly or wrongly) on the integrity or reliability of his subject or reveal idiosyncrasies or weaknesses, the subject's welfare or entire career may be harmed. Can such invasions of privacy be justified? It is said that taking a polygraph test is voluntary. Is it really voluntary, however, if a refusal can be interpreted as evidence of guilt or seems likely to jeopardize a job? These and similar questions cannot be answered by scientific investigation; they are questions for all citizens—including scientists—to consider.

The Author

BURKE M. SMITH is associate professor of neurology and psychiatry (clinical psychology) and chief clinical psychologist at the School of Medicine of the University of Virginia. He received all his formal education in Durham, N.C., where he was born; after progressing through the public schools he went to Duke University, where he obtained a bachelor's degree in biology in 1934, a master's degree in psychology in 1937 and a doctorate in psychology 10 years later. From 1947 to 1960 he was with the Veterans Administration, first as chief clinical psychologist at the mental hygiene clinic in Durham and then as chief of the clinical psychology service at the Veterans Administration Hospital in Roanoke, Va. He has held his present positions since 1961. Smith writes that most of his research activities "would come under the heading of psychophysiological" and that he is working now on "a comparative study of the effects of several drugs on the behavior of patients in interviews."

Bibliography

DON'T TRUST THE LIE DETECTOR. Richard A. Sternbach, Lawrence A. Gustafson and Ronald L. Colier in *Harvard Business Review*, Vol. 40, No. 6, pages 127–134; November–December, 1962.

LIE DETECTION AND CRIMINAL INTERROGATION. Fred E. Inbau and John E. Reid. The Williams & Wilkins Co., 1953.

PRINCIPLES OF PSYCHOPHYSIOLOGY. Richard A. Sternbach. Academic Press, 1966.

USE OF POLYGRAPHS AS "LIE DETECTORS" BY THE FEDERAL GOVERNMENT. House Report No. 198, 89th Congress, 1st Session. U.S. Government Printing Office, 1965.